



# Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete<sup>1</sup>

This standard is issued under the fixed designation C 42/C 42M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This test method covers obtaining, preparing, and testing (1) cores drilled from concrete for length or compressive strength or splitting tensile strength determinations and (2) beams sawed from concrete for flexural strength determinations.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens<sup>2</sup>

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)<sup>2</sup>

C 174/C 174M Test Method for Measuring Length of Drilled Concrete Cores<sup>2</sup>

C 496 Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens<sup>2</sup>

C 617 Practice for Capping Cylindrical Concrete Specimens<sup>2</sup>

C 642 Test Method for Density, Absorption, and Voids in Hardened Concrete<sup>2</sup>

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials<sup>2</sup>

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions<sup>2</sup>

C 1231/C 1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders<sup>2</sup>

### 2.2 ACI Standards:

318 Building Code Requirements for Structural Concrete<sup>3</sup>

## 3. Significance and Use

3.1 This test method provides standardized procedures for obtaining and testing specimens to determine the compressive, splitting tensile, and flexural strength of in-place concrete.

3.2 Generally, test specimens are obtained when doubt exists about the in-place concrete quality due either to low strength test results during construction or signs of distress in the structure. Another use of this method is to provide strength information on older structures.

3.3 Concrete strength is affected by the location of the concrete in a structural element, with the concrete at the bottom tending to be stronger than the concrete at the top. Core strength is also affected by core orientation relative to the horizontal plane of the concrete as placed, with strength tending to be lower when measured parallel to the horizontal plane.<sup>4</sup> These factors shall be considered in planning the locations for obtaining concrete samples and in comparing strength test results.

3.4 The strength of concrete measured by tests of cores and beams is affected by the amount and distribution of moisture in the specimen at the time of test. There is no standard procedure to condition a specimen that will ensure that, at the time of test, it will be in the identical moisture condition as concrete in the

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing Concrete for Strength.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.02.

<sup>3</sup> Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

<sup>4</sup> Neville, A., "Core Tests: Easy to Perform, Not Easy to Interpret," *Concrete International*, Vol. 23, No. 11, November 2001, pp. 59-68.

structure. The moisture conditioning procedures in this test method are intended to provide reproducible moisture conditions that minimize within-laboratory and between-laboratory variations and to reduce the effects of moisture introduced during specimen preparation.

3.5 There is no universal relationship between the compressive strength of a core and the corresponding compressive strength of standard-cured molded cylinders. The relationship is affected by many factors such as the strength level of the concrete, the in-place temperature and moisture history, and the strength gain characteristics of the concrete. Historically, it has been assumed that core strengths are generally 85 % of the corresponding standard-cured cylinder strengths, but this is not applicable to all situations. The acceptance criteria for core strength are to be established by the specifier of the tests. ACI 318 provides core strength acceptance criteria for new construction.

#### 4. Apparatus

4.1 *Core Drill*, for obtaining cylindrical core specimens with diamond impregnated bits attached to a core barrel.

4.2 *Saw*, for cutting beam specimens to size for flexural strength tests and to trim ends of cores. The saw shall have a diamond or silicon-carbide cutting edge and shall be capable of cutting specimens that conform to the prescribed dimensions, without excessive heating or shock.

#### 5. Sampling

##### 5.1 General:

5.1.1 Samples of hardened concrete for use in the preparation of strength test specimens shall not be taken until the concrete is strong enough to permit sample removal without disturbing the bond between the mortar and the coarse aggregate (see Note 1 and Note 2). When preparing strength test specimens from samples of hardened concrete, samples that have been damaged during removal shall not be used unless the damaged portion(s) are removed and the resulting test specimen is of suitable length (see 7.2). Samples of defective or damaged concrete that cannot be tested shall be reported along with the reason that prohibits use of the sample for preparing strength test specimens.

NOTE 1—Practice C 823 provides guidance on the development of a sampling plan for concrete in constructions.

NOTE 2—It is not possible to specify a minimum age when concrete is strong enough to withstand damage during removal, because the strength at any age depends on the curing history and strength grade of the concrete. If time permits, the concrete should not be removed before it is 14 days old. If this is not practical, removal of concrete can proceed if the cut surfaces do not display erosion of the mortar and the exposed coarse aggregate particles are embedded firmly in the mortar. In-place test methods may be used to estimate the level of strength development prior to attempting removal of concrete samples.

5.1.2 Specimens containing embedded reinforcement shall not be used for determining compressive, splitting tensile, or flexural strength.

5.2 *Core Drilling*—A core specimen shall be drilled perpendicular to the surface and not near formed joints or obvious edges of a unit of deposit. Record and report the approximate angle between the longitudinal axis of the drilled core and the

horizontal plane of the concrete as placed. A specimen drilled perpendicular to a vertical surface, or perpendicular to a surface with a batter, shall be taken from near the middle of a unit of deposit when possible.

5.3 *Slab Removal*—Remove a slab sufficiently large to secure the desired test specimens without the inclusion of any concrete that has been cracked, spalled, undercut, or otherwise damaged.

### DRILLED CORES

#### 6. Measuring the Length of Drilled Cores

6.1 Cores for determining the thickness of pavements, slabs, walls or other structural elements shall have a diameter of at least 3.75 in. [95 mm] when the lengths of such cores are stipulated to be measured in accordance with Test Method C 174/C 174M.

6.2 For cores that are not intended for determining structural dimensions, measure the longest and shortest lengths on the cut surface along lines parallel to the core axis. Record the average length to the nearest ¼ in. [5 mm].

#### 7. Cores for Compressive Strength

7.1 *Diameter*—The diameter of core specimens for the determination of compressive strength in load bearing structural members shall be at least 3.70 in. [94 mm]. For non-load bearing structural members or when it is impossible to obtain cores with length-diameter ratio (L/D) greater than or equal to 1, core diameters less than 3.70 in. [94 mm] are not prohibited (see Note 3). For concrete with nominal maximum aggregate size greater than or equal to 1½ in. [37.5 mm], the core diameters shall be as directed by the specifier of the tests (see Note 4).

NOTE 3—The compressive strengths of nominal 2-in. [50-mm] diameter cores are known to be somewhat lower and more variable than those of nominal 4-in. [100-mm] diameter cores. In addition, smaller diameter cores appear to be more sensitive to the effect of the length-diameter ratio.<sup>5</sup>

NOTE 4—The preferred minimum core diameter is three times the nominal maximum size of the coarse aggregate but it should be at least two times the nominal maximum size of the coarse aggregate.

7.2 *Length*—The preferred length of the capped or ground specimen is between 1.9 and 2.1 times the diameter. If the ratio of the length to the diameter (L/D) of the core exceeds 2.1, reduce the length of the core so that the ratio of the capped or ground specimen is between 1.9 and 2.1. Core specimens with length-diameter ratios equal to or less than 1.75 require corrections to the measured compressive strength (see 7.9.1). A strength correction factor is not required for L/D greater than 1.75. A core having a maximum length of less than 95 % of its diameter before capping or a length less than its diameter after capping or end grinding shall not be tested.

7.3 *Moisture Conditioning*—Test cores after moisture conditioning as specified in this test method or as directed by the specifier of the tests. The moisture conditioning procedures

<sup>5</sup> Bartlett, F.M. and MacGregor, J.G., "Effect of Core Diameter on Concrete Core Strengths," *ACI Materials Journal*, Vol. 91, No. 5, September-October 1994, pp. 460-470.

specified in this test method are intended to preserve the moisture of the drilled core and to provide a reproducible moisture condition that minimizes the effects of moisture gradients introduced by wetting during drilling and specimen preparation.

7.3.1 After cores have been drilled, wipe off surface drill water and allow remaining surface moisture to evaporate. When surfaces appear dry, but not later than 1 h after drilling, place cores in separate plastic bags or nonabsorbent containers and seal to prevent moisture loss. Maintain cores at ambient temperature, and protect cores from exposure to direct sunlight. Transport the cores to the testing laboratory as soon as practicable. Keep cores in the sealed plastic bags or nonabsorbent containers at all times except during end preparation and for a maximum time of 2 h to permit capping before testing.

7.3.2 If water is used during sawing or grinding of core ends, complete these operations as soon as practicable, but no later than 2 days after drilling of cores unless stipulated otherwise by the specifier of tests. After completing end preparation, wipe off surface moisture, allow the surfaces to dry, and place the cores in sealed plastic bags or nonabsorbent containers. Minimize the duration of exposure to water during end preparation.

7.3.3 Allow the cores to remain in the sealed plastic bags or nonabsorbent containers for at least 5 days after last being wetted and before testing, unless stipulated otherwise by the specifier of tests.

NOTE 5—The waiting period of at least 5 days is intended to reduce moisture gradients introduced when the core is drilled or wetted during sawing or grinding.

7.3.4 When direction is given to test cores in a moisture condition other than achieved by conditioning according to 7.3.1, 7.3.2, and 7.3.3, report the alternative procedure.

7.4 *Sawing of Ends*—The ends of core specimens to be tested in compression shall be flat, and perpendicular to the longitudinal axis. If necessary, saw the ends of cores that will be capped so that the following requirements are met:

7.4.1 Projections, if any, shall not extend more than 0.2 in. [5 mm] above the end surfaces.

7.4.2 The end surfaces shall not depart from perpendicularity to the longitudinal axis by more than 0.5 degrees.

7.5 *Density*—When required by the specifier of the tests, determine the density by weighing the core before capping and dividing the mass by the volume of the core calculated from the average diameter and length. Alternatively, determine the density from the mass in air and submerged mass in accordance with Test Method C 642. After submerged weighing, dry cores in accordance with 7.3.2 and store in sealed plastic bags or nonabsorbent containers for at least 5 days before testing.

7.6 *Capping*—If the ends of the cores do not conform to the perpendicularity and planeness requirements of Test Method C 39/C 39M, they shall be sawed or ground to meet those requirements or capped in accordance with Practice C 617. If cores are capped in accordance with Practice C 617, the capping device shall accommodate actual core diameters and produce caps that are concentric with the core ends. Measure

core lengths to the nearest 0.1 in. [2 mm] before capping. Unbonded caps in accordance with Practice C 1231/C 1231M are not permitted.

7.7 *Measurement*—Before testing, measure the length of the capped or ground specimen to the nearest 0.1 in. [2 mm] and use this length to compute the length-diameter (L/D) ratio. Determine the average diameter by averaging two measurements taken at right angles to each other at the midheight of the specimen. Measure core diameters to the nearest 0.01 in. [0.2 mm] when the difference in core diameters does not exceed 2 % of their average, otherwise measure to the nearest 0.1 in. [2 mm]. Do not test cores if the difference between the largest and smallest diameter exceeds 5 % of their average.

7.8 *Testing*—Test the specimens in accordance with Test Method C 39/C 39M. Test the specimens within 7 days after coring, unless specified otherwise.

7.9 *Calculation*—Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen.

7.9.1 If the ratio of length to diameter (L/D) of the specimen is 1.75 or less, correct the result obtained in 7.9 by multiplying by the appropriate correction factor shown in the following table (see Note 6):

Ratio of Length to Diameter (L/D)	Strength Correction Factor
1.75	0.98
1.50	0.96
1.25	0.93
1.00	0.87

Use interpolation to determine correction factors for L/D values not given in the table.

NOTE 6—Correction factors depend on various conditions such as moisture condition, strength level, and elastic modulus. Average values for corrections due to length-diameter ratio are given in the table. These correction factors apply to low-density concrete having a density between 100 and 120 lb/ft<sup>3</sup> [1600 and 1920 kg/m<sup>3</sup>] and to normal density concrete. They are applicable to both dry and wet concrete for strengths between 2000 psi and 6000 psi [14 MPa to 42 MPa]. For strengths above 10000 psi [70 MPa], test data on cores show that the correction factors may be larger than the values listed above.<sup>6</sup>

7.10 *Report*—Report the results as required by Test Method C 39/C 39M with the addition of the following information:

7.10.1 Length of core as drilled to the nearest ¼ in. [5 mm],

7.10.2 Length of test specimen before and after capping or end grinding to the nearest 0.1 in. [2 mm], and average diameter of core to the nearest 0.01 in. [0.2 mm] or 0.1 in. [2 mm],

7.10.3 Compressive strength to the nearest 10 psi [0.1 MPa] when the diameter is measured to the nearest 0.01 in. [0.2 mm] and to the nearest 50 psi [0.5 MPa] when the diameter is measured to the nearest 0.1 in. [2 mm], after correction for length-diameter ratio when required,

7.10.4 Direction of application of the load on the specimen with respect to the horizontal plane of the concrete as placed,

<sup>6</sup> Bartlett, F.M. and MacGregor, J.G., "Effect of Core Length-to-Diameter Ratio on Concrete Core Strengths," *ACI Materials Journal*, Vol. 91, No. 4, July-August 1994, pp. 339-348.

7.10.5 The moisture conditioning history:

7.10.5.1 The date and time core was obtained and first placed in sealed bag or nonabsorbent container,

7.10.5.2 If water was used during end preparation, the date and time end preparation was completed and core placed in sealed bag or nonabsorbent container,

7.10.6 The date and time when tested,

7.10.7 Nominal maximum size of concrete aggregate.

7.10.8 If determined, the density,

7.10.9 If applicable, description of defects in cores that could not be tested, and

7.10.10 If any deviation from this test method was required, describe the deviation and explain why it was necessary.

7.11 *Precision:*<sup>7</sup>

7.11.1 The single-operator coefficient of variation on cores has been found to be 3.2 %<sup>8</sup> for a range of compressive strength between 4500 psi [32.0 MPa] and 7000 psi [48.3 MPa]. Therefore, results of two properly conducted tests of single cores by the same operator on the same sample of material should not differ from each other by more than 9 %<sup>8</sup> of their average.

7.11.2 The multi-laboratory coefficient of variation on cores has been found to be 4.7 %<sup>8</sup> for a range of compressive strength between 4500 psi [32.0 MPa] and 7000 psi [48.3 MPa]. Therefore, results of two properly conducted tests on cores sampled from the same hardened concrete (where a single test is defined as the average of two observations (cores), each made on separate adjacent drilled 4 in. [100 mm] diameter cores), and tested by two different laboratories should not differ from each other by more than 13 %<sup>8</sup> of their average.

7.12 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

## 8. Cores for Splitting Tensile Strength

8.1 *Test Specimens*—The specimens shall conform to the dimensional requirements in 7.1, 7.2, 7.4.1 and 7.4.2. Ends are not to be capped.

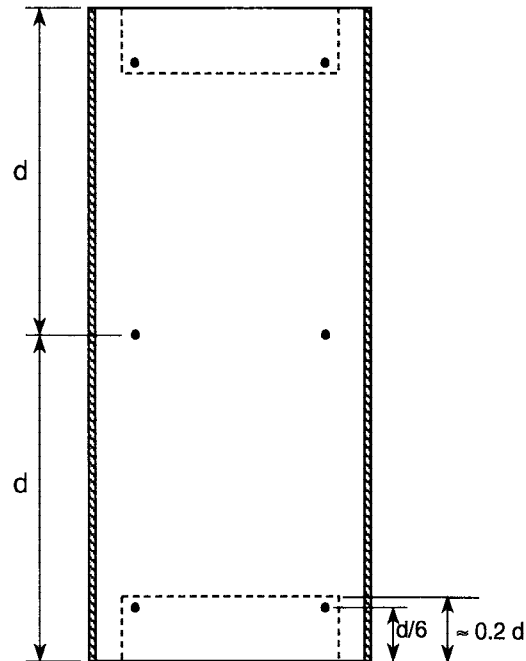
8.2 *Moisture Conditioning*—Condition the specimens as described in 7.3, or as directed by the specifier of tests.

8.3 *Bearing Surfaces*—The line of contact between the specimen and each bearing strip shall be straight and free of any projections or depressions higher or deeper than 0.01 in. [0.2 mm]. When the line of contact is not straight or contains projections or depressions having heights or depths greater than 0.01 in., grind or cap the specimen so as to produce bearing lines meeting these requirements. Do not test specimens with projections or depressions greater than 0.1 in. [2.0 mm]. When capping is employed, the caps shall be as thin as practicable and shall be formed of high-strength gypsum plaster.

NOTE 7—Fig. 1 illustrates a device suitable for applying caps to the

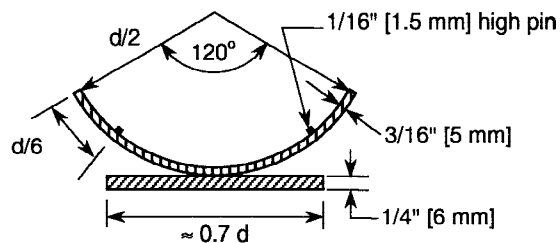
<sup>7</sup> Bollin, G. E., "Development of Precision and Bias Statements for Testing Drilled Cores in Accordance with ASTM C 42," *ASTM Journal of Cement, Concrete, and Aggregates*, Vol 15, No. 1, 1993.

<sup>8</sup> These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.



PLAN

$d$  = nominal core diameter



ELEVATION

FIG. 1 Suitable Capping Device for Splitting Tensile Strength Test

bearing surfaces of core specimens.

8.4 *Testing*—Test the specimens in accordance with Test Method C 496.

8.5 *Calculation and Report*—Calculate the splitting tensile strength and report the results as required in Test Method C 496. When grinding or capping of the bearing surfaces is required, measure the diameter between the finished surfaces. Indicate that the specimen was a core and provide the moisture conditioning history as in 7.10.5.

8.6 *Precision:*<sup>9</sup>

8.6.1 The within laboratory single operator coefficient of variation for splitting tensile strength between 520 psi [3.6 MPa] and 590 psi [4.1 MPa] of cores has been found to be 5.3 %<sup>8</sup>. Therefore, results of two properly conducted tests by

<sup>9</sup> Steele, G.W., "Portland Cement Concrete Core Proficiency Sample Program," Strategic Highway Research Program, SHRP-P-636, National Research Council, Washington, D.C., 1993.





the same operator in the same laboratory on the same sample of material should not differ by more than 14.9 %<sup>8</sup> of their average.

8.6.2 The multi-laboratory coefficient of variation for splitting tensile strength between 520 psi [3.6 MPa] and 590 psi [4.1 MPa] of cores has been found to be 15.0 %<sup>8</sup>. Therefore, results of two properly conducted tests on the same sample of material of hardened concrete and tested by two different laboratories should not differ from each other by more than 42.3 %<sup>8</sup> of their average.

8.7 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

## **BEAMS FOR FLEXURAL TESTING**

### **9. Flexural Strength**

9.1 *Test Specimens*—Unless otherwise specified, a beam specimen for the determination of flexural strength shall have a nominal cross section of 6 by 6 in. [150 by 150 mm] (Note 8). The specimen shall be at least 21 in. [530 mm] in length, but when two tests for flexural strength are to be made in one beam specimen, it shall be at least 33 in. [840 mm] in length. Perform the sawing operation so that the concrete will not be weakened by shock or by heating. The sawed surfaces shall be smooth, plane, parallel, and free from steps, ridges, and grooves. Take care in handling sawed beam specimens to avoid chipping or cracking.

NOTE 8—In many cases, particularly with prisms cut from pavement slabs, the width will be governed by the size of the coarse aggregate and the depth by the thickness of the slab.

9.2 *Moisture Conditioning*—Protect the surfaces of sawed specimens from evaporation by covering them with wet burlap and plastic sheeting during transportation and storage. Test the specimens within 7 days of sawing. Submerge the test specimens in lime-saturated water at  $73.5 \pm 3.5^{\circ}\text{F}$  [ $23.0 \pm 2.0^{\circ}\text{C}$ ] for at least 40 h immediately prior to the flexure test. Test the specimens promptly after removal from water storage. During

the period between removal from water storage and testing, keep the specimens moist by covering with a wet blanket of burlap or other suitable absorbent fabric.

9.2.1 When the specifier of tests so directs, beams shall be tested in a moisture condition other than that achieved by conditioning in accordance with 9.2.

NOTE 9—Relatively small amounts of drying of the surface of flexural specimens induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9.3 *Testing*—Test the specimens in accordance with the applicable provisions of Test Method C 78.

NOTE 10—Sawing may greatly reduce the indicated flexural strength; beams shall, therefore, be tested with a molded surface in tension whenever possible. The location of the tension face with respect to the position of the concrete as placed and the position of the sawed surfaces should be reported.

9.4 *Report*—Report the results in accordance with the applicable provisions of Test Method C 78 and the requirements of this test method, including the moisture condition at the time of testing. Identify orientation of the specimen's finished, sawed, and tension faces with respect to their positions in the test apparatus.

### **10. Precision and Bias**

10.1 *Precision*—Data are not available for preparing a statement on the precision of flexural strength measured on sawed beams.

NOTE 11—Users of this method who have replicate test data that may be appropriate for a statement on repeatability are encouraged to contact the chairman of the subcommittee.

10.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

### **11. Keywords**

11.1 compressive strength; concrete coring; concrete sawing; concrete strength; flexural strength; splitting tensile strength

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